10/505297
3/PRTS
DT05 Rec'd PCT/PTO 20 AUG 2004

GAS SEAL SYSTEM FOR THE SHAFT OF AN ELECTRIC COMPRESSOR MOTOR.

The present invention relates to the provision of a secure environment for an electric motor of the type in which a single housing accommodates both the motor and rotating machinery driven by the motor.

The invention will be described with reference to a motor used to drive a compressor. The invention is however applicable to other sorts of rotating machinery such as centrifugal pumps. For ease of installation and retrieval, a single housing accommodating an electric motor and a compressor is sometimes employed. Such an arrangement is particularly useful for sub-sea applications in which easy installation and retrieval are important. Figure 1 shows a schematic representation of a typical prior art arrangement including a motor 2 linked to a compressor unit 4 by means of a shaft 6 mounted in bearings 8 and 10. All of these components are mounted in a single housing 12. Inlet pipe 14 and outlet pipe 16 lead gas respectively into and out of the compressor 12. Since a certain amount of gas being compressed will pass through the bearing 8 into the area surrounding the motor 2, the arrangement is only suitable for pumping dry gas because the motor will be damaged if exposed to moisture. Such a restriction makes the arrangement unsuitable for use in the pumping of gas from a hydrocarbon reservoir which will generally have a high water vapour content and contain droplets of water.

When such moisture laden gas is to be compressed, one solution is to use a more conventional arrangement such as that shown in Figure 2 in which the motor 2 is accommodated within a first housing 20 and the compressor unit 4 is accommodated within a separate second housing 22. Particularly when used in a sub-sea environment, it will be necessary to incorporate seals 18 where the shaft 6 passes through the walls of the housings 20 and 22. There is a further requirement in sub-sea applications for the apparatus to be compact which in turn means that high operating

speeds are necessary to achieve the required volumetric throughput and pressure increase. Such high operating speeds however lead to rapid deterioration of the seals 18. In sub-sea applications, where replacement is difficult and may involve stopping production from all or part of the oil field, this is a severe disadvantage. The object of the invention is to overcome at least some of the above described disadvantages of existing motor/compressor assemblies.

Thus according to the invention there is provided an assembly comprising a housing, an electric motor accommodated within a first portion of the housing, rotating machinery accommodated within a second portion of the housing and driven by the electric motor, separation means in the housing between the first and second portions thereof for separating fluid acted upon by the rotating machinery from the electric motor, gas introduction means for introducing at least substantially dry motor protection gas into the first housing portion and restricted gas flow means for permitting a leakage of the motor protection gas from the first housing portion into the second housing portion.

With such an arrangement, it is possible to provide a motor and compressor in the same housing which can be operated to compress gas regardless of its moisture content. Furthermore, seals around a drive shaft connecting the motor and compressor are not required.

Preferably the gas introduction means includes means for supplying the at least substantially dry gas. This may comprise a gas drying and supply unit on a remote host facility linked to the first housing portion by an umbilical.

The invention is particularly applicable to the driving of machinery for raising the pressure of fluid such as compressors or centrifugal pumps.

When the rotating machinery comprises a compressor, preferably the second housing portion includes a compressor inlet for receiving gas at a first pressure and a compressor outlet for delivering gas at a second pressure

higher than the first pressure and the gas flow means allows leakage of the motor protection gas into the second housing portion adjacent to the compressor inlet. In order to accommodate variations in pressure within the second housing portion, the assembly preferably also includes means for automatically maintaining the motor protection gas at a pressure above that of fluid in a part of the second housing portion adjacent to the gas flow means.

If this pressure differential is maintained at a low value, then the leakage of motor protection gas into the second housing portion can be kept to a minimum which will reduce the cost of running the assembly.

When the fluid being acted upon by the rotating machinery is a gas, the apparatus preferably includes circulating apparatus for diverting a portion of the acted upon gas to the first housing portion, the circulating apparatus including drying means for reducing the moisture content of the acted upon gas diverted back to the first housing portion. Such an arrangement will still further reduce the amount of motor protection gas which needs to be supplied and will still further reduce the cost of running the assembly. Furthermore, if the motor can tolerate wet gas for a short start up period without damage to its components, then the requirement for an external supply of motor protection gas can be obviated if such circulating apparatus is provided.

Conveniently the drying means separates the extracted portion of the acted upon gas into an at least substantially moisture-free first outlet flow and the circulating apparatus includes first routing means for routing the first outlet flow from a first outlet of the drying means to the housing first portion.

In order to facilitate removal of the extracted moisture, preferably the drying means incorporates moisture extracted from the first outlet flow into a second outlet flow.

The second outlet flow from the drying means can conveniently be

transported away from the assembly by means of the gas being acted upon by the compressor. Accordingly, the circulating apparatus preferably also includes second routing means for routing the second outlet flow containing the extracted moisture from a second outlet of the drying means and for incorporating it into the flow of gas acted upon by the compressor.

In order that the second outlet flow from the drying means can be incorporated into a relatively low pressure gas flow, preferably the second routing means incorporates the second outlet flow containing the extracted moisture into the acted upon gas at least substantially prior to it being acted upon by the compressor.

Alternatively, in order to avoid introducing additional moisture into gas entering the compressor, the second routing means incorporates the second outlet flow containing the extracted moisture into the acted upon gas at least substantially after it has been acted upon by the compressor.

So as to avoid the necessity of raising the pressure of the second outlet flow from the drying means to that of the gas leaving the compressor, preferably the second routing means includes a pressure equalising device such as an ejector for incorporating the second outlet flow containing the extracted moisture into acted upon gas downstream of the compressor.

Preferably one or more gas outlet flows from the drying means pass through non-return valves configured to prevent such flow or flows returning directly to outlets of the drying means.

The invention also provides a method of operating an electric motor accommodated in a first portion of a housing and arranged to drive a rotating machine accommodated in a second portion of the housing in which fluid in the second housing portion which is acted upon by the rotating machine is separated from the first housing portion by separation means, the method including the steps of:

(i) providing gas introduction means for introducing at least substantially

dry motor protection gas into the first housing portion;

(ii) providing restricted gas flow means between the first and second housing portions; and

(iii) establishing a leakage of the motor protection gas from the first housing portion to the second housing portion via the gas flow means.

In order to reduce the amount of motor protection gas consumed by the assembly, preferably the method involves providing circulating apparatus and diverting a portion of the acted upon gas to the first housing portion via the circulating apparatus, incorporating drying means in the circulating apparatus and reducing the moisture content of the acted upon gas diverted back to the first housing portion by means of the drying means.

The invention will now be described by way of example only with reference to the accompanying Figures in which:

Figure 1 shows in schematic form a prior art arrangement;

Figure 2 shows in schematic form a further prior art arrangement;

Figure 3 shows in schematic form a first embodiment of the invention; and

Figure 4 shows in schematic form a second embodiment of the invention.

The prior art arrangements shown in Figs. 1 and 2 have been described above.

In the first embodiment of the invention shown in Figure 3, an electric motor 30 is linked to a compressor 32 by a shaft 34 which is supported by a first bearing 36 and a second bearing 38. These components are accommodated in a housing 40 having first and second portions 42 and 44 respectively accommodating the motor 30 and the compressor 32. Separation means, in the form of a wall 46, separates the housing portions 42 and 44 from each other.

Gas introduction means, in the form of an umbilical 48 leads to an inlet 50 of the first housing portion 42 for supplying at least substantially

dry, and more preferably completely dry, motor protection gas 52 thereinto.

Gas flow means 54, comprising one or more passages between the first and second housing portions 42 and 44, are provided to allow a leakage of the motor protection gas 52 from the first housing portion 42 into the second housing portion 44. This leakage is indicated by arrows A.

The compressor 32 includes an inlet 56 connected to an inlet pipe 58 (at pressure p1) and an outlet 60 connected to an outlet pipe 62 (at a higher pressure p2).

The first housing portion 42 containing the motor is maintained at a pressure p3 by the supply of motor protection gas 52. p3 is maintained higher than p1 in order that motor protection gas 52 steadily leaks through the gas flow means 54 in the direction of arrows A into the second housing portion. This pressure differential prevents any of the gas supplied to the compressor via inlet pipe 58, which may contain moisture, from entering the first housing portion 42. Control means (not shown) are preferably provided to maintain p3 only slightly above p1 in order that only a low volumetric flow of motor protection gas through the gas flow means 54 occurs. This will reduce the amount of motor protection gas required, and thereby minimise running costs.

The so-called integrated oil-free motor compressor manufactured by Man Turbo Maschinen AG would be the type of motor compressor assembly to which the invention could be applied.

The second embodiment of the invention will now be described with reference to Figure 4 in which parts which correspond in form and function to those shown in Figure 3 are indicated with like numerals prefixed with 1 and will not be described again in detail.

The embodiment shown in Figure 4 includes circulating apparatus shown generally as 170. An extraction pipe 172 is arranged to extract a portion, for example 10%, of the gas leaving the compressor via the outlet pipe 162 and route it to a gas drying unit 174. The gas drying unit 174 may

suitably be of the type manufactured under the name TWISTER by Shell and its partner Stork Product Engineering. This drying unit uses a Laval nozzle to expand gas to supersonic velocities leading to low temperature and pressure resulting in nucleation and condensation of water. Droplets of water formed come into contact with a wing member and are centrifuged onto walls of the device. A first flow 176 of at least substantially dry gas (at pressure P3) leaves the gas drying unit via a first gas outlet 178 and is routed by dry gas conduit 182 via a non-return valve 180 to the umbilical 148 immediately upstream of the housing first portion 142 and downstream of a further non-return valve 184 in the umbilical 148. The pressure P3 is arranged to be greater than the pressure P5 of gas entering the compressor.

Since the motor 130 may be able to tolerate wet gas for a short start up period without damage to its components, the umbilical 148 for supplying dry gas may not be necessary in which case the dry gas conduit 182 would lead directly into the housing first portion 142.

A second flow 186 of wet gas (at pressure P4) containing all, or substantially all, of the water contained in the gas extracted from the compressor outlet pipe leaves the gas drying unit 174 via a second outlet 188 and is routed by a wet gas conduit 190 to the inlet pipe 158 through a further non-return valve 192. The pressure P4 is arranged to be greater than P1, the pressure of gas approaching the compressor through the inlet pipe 158. This flow of wet gas 186 will assist the flow of new gas entering the compressor from the inlet pipe 158.

Alternatively, the second outlet 188 of the gas drying unit 174 may be connected by a high pressure wet gas conduit 193 which routes the wet gas 186 through a non-return valve 194 to an ejector 196 which acts to entrain the wet gas 186 into the flow of pressurised gas leaving the compressor via the outlet 160. The ejector 196 is necessary because the pressure P4 of the wet gas will be lower than the pressure P2 of the gas at the compressor outlet 160. Downstream of the ejector 196 the pressure P6

of the combined gas streams will be less than P2 but high enough to ensure satisfactory conveyance of the gas to the host facility. The alternative route for the wet gas 186 avoids reintroducing the moisture extracted by the gas drying unit 174 back into the compressor.

As in the first embodiment, the pressure of gas in the housing first portion 142 will be arranged to be slightly higher than the pressure P5 of gas entering the compressor so as to ensure that a steady leakage (A) of at least substantially dry gas from the first housing portion to the second is maintained and flow in the reverse direction is prevented.